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LONGWALL GATESIDE PACKS: PART II
DESIGN METHODS

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DESIGN METHODS

by

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ABSTRACT

Pack design methods based on engineering principles are a relatively new phenomena and are slowly being applied in practice. Two design methods have been published, the detached roof block concept and the roof beam tilt concept. Both of these methods are described in this report.

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MURS DE REMBLAI POUR L'EXPLOITATION PAR LONGUE TAILLE: PARTIE II
MÉTHODES DE CONCEPTION

par

P. Cain*

RÉSUMÉ

Les méthodes de conception des remblais conçues d'après des principes d'ingénierie sont un phénomène relativement nouveau et de plus en plus appliquées dans la pratique. On vient de publier deux méthodes de conception suivant les concepts du "detached roof block" et du "roof beam tilt". Le présent rapport donne une brève description des deux méthodes susmentionnées.

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INTRODUCTION

The gateside pack is arguably the most important element in the gateroad support system. Without an adequate gateside pack, gateroads serving longwall coalfaces rapidly deteriorate with consequent deleterious effects on transport, ventilation and productivity and the increased possibility of accidents at the face end.

Developments in the design of packs have not kept pace with improvements in the design of other aspects of longwall extraction. The recent proliferation of packing methods, particularly monolithic packing systems, gives the mine planner a wide range of available options, but no means to evaluate them. As a result, gateroads may be expensively oversupported or disastrously undersupported.

These deficiencies were corrected in part with the publication by Whittaker and Woodrow (1) of design criteria for gateside packs which were derived from the detached roof block concept of maximum loads on face supports published by Wilson (2). More recently, the recognition of the development of a tilting beam in the strata overlying the pack and the roadway resulting in differential loading of the roadway support system was described by Smart et al. (3). This report reviews both methods of pack design.

DESIGN METHODS FOR GATESIDE PACKS

The dimensions and composition of gateside packs has in the past been the product of local custom and experience. This practice, whilst often satisfactory, has the disadvantage that the design of packing systems not previously used in a particular mine has to be applicable under prevailing conditions at the new locality.

Although a gateside pack is a comparatively simple, passive support structure, the environment in which it is installed and its interaction with the adjacent strata is complex and perhaps not fully understood. The design methods applied are therefore simplified to take account of this lack of

knowledge. The degree of simplification varies, but in some respects is not too great a disadvantage, as it allows for a wider use of the criteria.

The simplest design processes express pack width in terms of the extracted seam height. In the U.K., the generally accepted pack width requirement is 1.5 - 3 h, where h is the extracted height, although packs may be made wider than this to dispose of ripping debris. In Germany, where more rigid anhydrite packs are more common, the range is between 0.5 - 1 h depending upon an index which describes the bearing capacity of the floor. Local response to pack induced problems also varies. A frequent result of pack loading is penetration of the floor or roof by the pack. In the U.K., the accepted response to this is to increase the pack width, therefore distributing the load over a larger surface. In Germany, where rigid packs are used, the response is to reduce the pack width, allowing it to yield instead of penetrate.

Both of the above design methods are empirical and based upon local experience with local pack materials, but on closer examination, engineering concepts can be seen behind each of them.

Two recently developed design methods offer to put the design of gateroad packs on a more sound engineering basis. The detached roof block concept was proposed by Whittaker and Woodrow (1) and is a development of a static analysis of maximum loads on longwall coalface supports. The roof beam tilt concept, recently described by Smart et al. (3) relies to a much greater extent on field data, but allows the evaluation of the effects of alternate pack designs.

THE DETACHED ROOF BLOCK CONCEPT

A gateside pack lies between the high strata pressure zone located in the solid and the low pressure zone of the caved waste. The pressure differential encourages pack loading by the formation of a detached block in the roof strata above the pack and the roadway (Figure 1). The basis of the design method is to calculate the maximum load that would be imposed on a pack at the face end if such a detached block were to form.

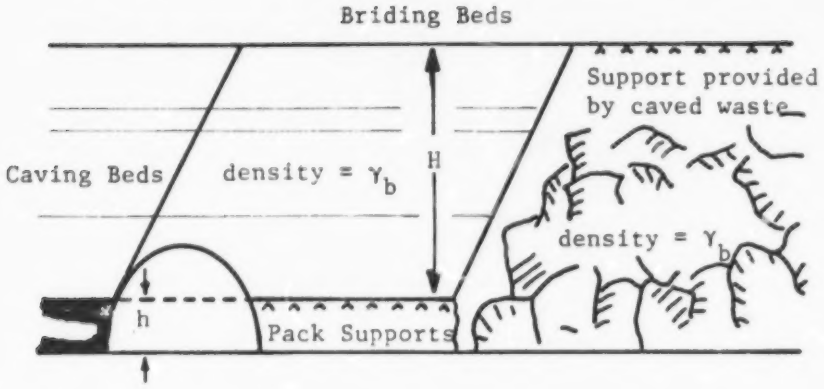


Figure 1 - Detached roof block concept

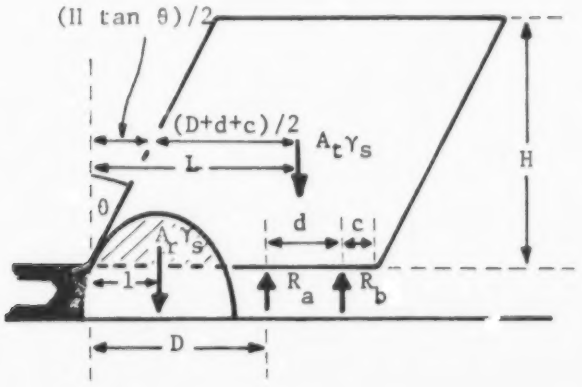


Figure 2 - Calculation parameters

CONCEPT GEOMETRY

The free surfaces of the roof block described above are formed by an assumed ribside shear plane extending to a bedding separation plane between the caving beds and the bridging beds, a parallel gobside fracture and the top of the seam. All of the calculation parameters (Figure 2) can be measured directly or are assumed from the design concept except the height of the detached block.

In principle, the height to which caving extends, H, is function of the extracted height, h, and the degree of fragmentation that occurs in the waste. Since the mass of the caved material remains the same after caving:

$$(H + h)\gamma_b = H\gamma_s$$

$$H = h \frac{\gamma_b}{\gamma_s - \gamma_b} \qquad \text{Eq 1}$$

where γ_s and γ_b are the solid density and the broken density of the roof strata respectively. In the absence of definitive values of these parameters, the authors suggest a value of H of four times the seam height.

ANALYSIS OF PACK LOADING

Whittaker and Woodrow (1) assumed that the mass of the detached block is supported only by the pack, i.e. roadway lining resistance is negligible and that no reaction is generated at the sides of the block or at roof level. Taking a simple case where the roof block rests on two rows of supports, R_a and R_b (Figure 2), the block is at rest under the action of gravity and can be considered as a rigid body in equilibrum under the action of three forces in a plan, when the sum of the forces is zero and when the sum of the moments of the forces about any point in the plane is zero. With reference to Figure 2, values for R_a and R_b can be derived as follows:

$$R_a = \frac{\gamma_s}{d}\left[\tfrac{1}{2}H(D + d - c - H \tan\theta)(D + d + c) - Ar(D + d - L)\right] \qquad \text{Eq 2}$$

$$R_b = \frac{\gamma_s}{d}\left[\tfrac{1}{2}H(H \tan\theta - D + d + c)(D + d + c) + Ar(D - L)\right] \qquad \text{Eq 3}$$

Values of R_a and R_b are given in kg/m run of roadway.

Where a single element is used as a pack support, i.e. monolithic packs, stone packs or single wood chocks, the location of the resistance offered by the pack must be directly below the centre of gravity of the roof block. For multiple elements, the resultant of the elemental resistances must be directly below the centre of gravity of the roof block. Thus the resistance required of each element and therefore the required properties of each element are dependent on the overall geometry of the face end. It follows, therefore, that the location of the pack resultant can be changed by altering the properties of the pack elements.

THE ROOF BEAM TILT CONCEPT

The roof beam tilt concept develops the hypothesis that the variation of the properties of individual pack elements can be used to modify the location of the resultant and hence the roadway behaviour. It is based on the following appreciation of the strata control function of a permanent support system comprising pack and roadway supports [after Smart et al. (3)], and relied heavily on information gathered in situ rather than theoretical determination of required resistance:

1. The function of the permanent support system is to control the convergence of the immediate roof, which is considered to span laterally from the waste edge of the roadside pack to a point in over the ribside and to extend vertically to a height determined by the caving characteristics of the seam.

2. The forces which cause the convergence of the roof into the void created by the seam extraction are due to the weight of the immediate roof itself plus a distributed loading transmitted from the superincumbent strata and it is these forces which the permanent support system must control by generating sufficient reaction between roof and floor, this reaction being augmented by the

inherent strength of the immediate roof itself. Considering the relative strengths of pack and roadside support, it is probable that in most cases the pack will be capable of generating a much larger proportion of the total reaction than the roadway supports.

3. As convergence between the roof and floor generally increases across the section of the permanent support system from ribside to waste, it is best to consider convergence as a subsidence profile, i.e. the lowest subsidence profile generated by the longwall.

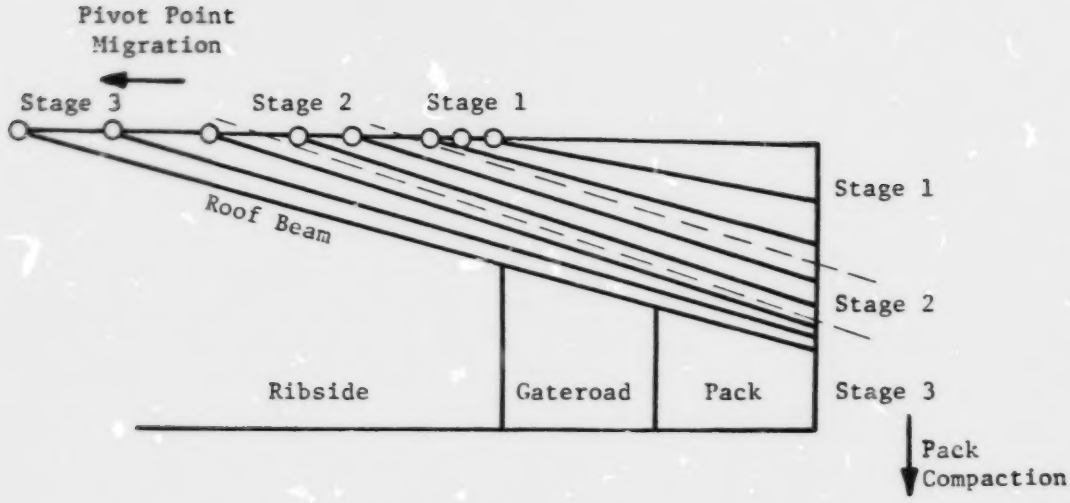
4. It appears that the subsidence of the immediate roof can be described by considering the roof strata to tilt about a notional pivot point located in over the ribside. Both the angle of tilt and the location of the pivot point within the ribside change with longwall advance and time, the change being divided into three 'stages', as illustrated in Figure 3.

5. Fundamental to the pack design method is the generation of sufficient support resistance to prevent subsidence development beyond Stage 1, i.e. the natural tendency for subsidence to develop must be modified by the action of the pack or else much of the inherent strength of the roof strata will be destroyed resulting in excessive roadway deformation.

Accepting the combination of the parameters roof-strata-tilt and pivot point location as an approximate mathematical representation of roof subsidence, appropriate pack designs can be developed from in situ information.

ANALYSIS OF PACK LOADING

The analysis of pack loading is based on the development of a linear roof beam tilt across the roadway. This can be determined from either direct measurement using inclinometers or from closure data from different points across the roadway/pack. Knowing the roof beam tilt, the amount of closure at any point in the roadway and the distance of that point from the ribside, the location of the pivot point can also be determined.



Stage 1 - Roof beam tilt increasing pack compaction > pivot point migration

Stage 2 - Roof beam tilt = constant pack compaction = pivot point migration

Stage 3 - Roof beam tilt decreasing pack compaction > pivot point migration

Figure 3 - Explanation of roof beam tilt in terms of pack compaction and pivot point migration

Once the location of the pivot point and the tilt angle have been calculated, closure can be determined for pack elements, so long as their distance from the pivot point is known and the roof beam is assumed to remain linear. Loads on individual pack elements may then be determined mathematically or empirically from in situ measurements of pack stresses and strains. The total load generated by all pack elements in the roadway can then be expressed in terms of MN/m run of roadway and the location of the pack load resultant can be determined by taking moments about the pivot point.

Combining this information with a knowledge of the stress/strain characteristics of alternative pack elements allows alternative pack designs to be evaluated in terms of their support resistance. Thus if the initial conditions represent gateroad stability in terms of control of subsidence across the roadway and pack, equivalent resistances provided by alternate pack designs should also provide stability.

Since the method of analysis also allows the determination of bearing pressures, these can be matched to the bearing capabilities of the roof and floor to prevent failure.

DISCUSSION

The fundamental shortcoming of the detached block concept as a method of pack design is immediately apparent from this treatment. The pack elements are essentially passive structures so no load will be generated without closure. Since the stress/strain characteristics also vary with element type and imposed stress, the process of modelling the pack resistance and the conditions of equilibrium for the detached block is extremely difficult. This difficulty is further compounded by even a small increase in the number of pack elements.

A more telling criticism is that the calculated design loads are considerably less then those experienced in situ. The basis of the roof beam tilt concept is that in situ stability is defined by in situ measurements and a design hypothesis used to ensure that pack modifications maintain the roof beam tilt and pack loading within stable limits. The ability of the method to make use of the stress/strain data for elements from other investigation

sites makes the method applicable to a wider range of pack designs and allows a mine planner to experiment with a wide range of materials.

Thus it is apparent that the roof beam tilt approach to pack design is better suited to comparisons of the effectiveness of different pack types in any given situation, once the stability criteria for the gateroad are known, i.e. maximum roof beam tilt and total pack resistance. The maximum allowable roof beam tilt suggested by Smart et al. (3) was 3°, although this will vary with the competency and length of the roof beam. An approximation of the required pack resistance for a given seam height has been derived, based on roof beam tilt analysis at two locations (4) (Figure 4), but this does not appear to be generally applicable, as two other pack resistances calculated from data available for the Sydney Coalfield and Gardannes Mine in Provence, France are well below the design curve. In both cases the roadways were stable.

It appears, therefore, that although the roof beam tilt method of pack design is more flexible than the detailed block concept, it is dependent to a large extent on detailed site investigation data.

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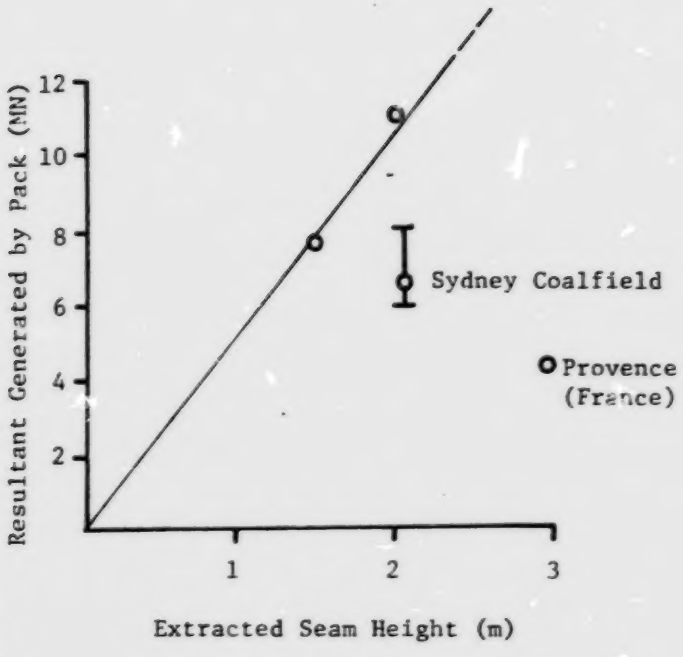

Figure 4 - Proposed relationship between extracted height and required resultant (after Smart et al.) also showing data from Canada and France